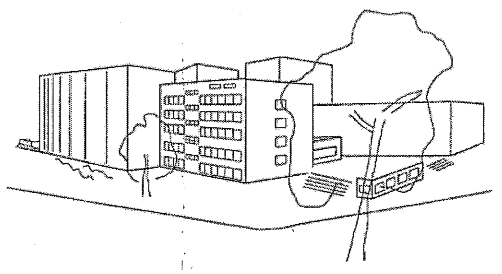
Bereich Hochspannungsprüftechnik
Institut für Elektroenergiesysteme und Hochspannungstechnik



Universität Fridericiana (TH) Karlsruhe
76128 Karlsruhe - Kaiserstraße 12
Telefon (0721) 608 2520 Telefax (0721) 69 52 24

Test Report No 2009-124

Type Test of a 72,5 kV- Molded Rubber Termination QTEN

Client: 3M Deutschland GmbH
Carl-Schurzstr.1

41453 Neuss

Reporter: Dr.-Ing. R. Badent
Dr.-Ing. B. Hoferer

1 Purpose of Test

A 72,5 kV-Molded Rubber Termination was subjected to a type test according to IEC 60840 04/2004 type test on accessories, chapter 14.3.2 and additional customer´s specification.

2 Miscellaneous Data

Test object:	*72,5 kV - Molded Rubber Termination for outdoor application 3 M QTEN* *Type 96-EP 720-2 , XE - 0091 - 3568 - 4* *Installation instruction AABBCC 75657 from 02.02.2010, Figure 2.1 - 2.8* *Material list AABBCC 75665 from 02.02.2010, Figure 2.9* - The termination was mounted on a single core XLPE insulated cable with Aluminium conductor 1000mm^2, 66 (72,5) kV, nominal insulation thickness 9 mm^2, Figure 2.10.	
Manufacturer:	3M Deutschland GmbH Carl-Schurzstr. 1 41453 Neuss	
Place of test:	*Institute of Electric Energy Systems and High-Voltage Technology* – University of Karlsruhe Kaiserstraße 12 – 76128 Karlsruhe	
Testing dates:	Delivery:	14.12.2009
	Mounting:	14.12. – 17.12.2009
	Test date:	18.12.2009 – 28.01.2010
Atmospheric conditions:	Temperature:	19°C - 23°C
	Air pressure:	980 - 1020 mbar
	rel. humidity:	35% - 50%
Representatives	*Client´s representatives* Dipl.-Ing. J. Weichold, 3M Germany *Representatives responsible for the tests* Dr.-Ing. R. Badent Dr.-Ing. B. Hoferer Mr. O. Müller	

3M QTEN

Prüfgegenstand entspricht der vorgelegten technischen Zeichnung

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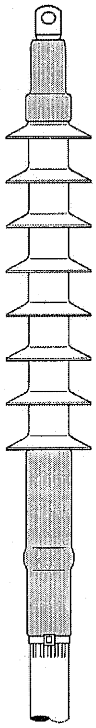

Kit No.	96-EP 720-2
Conductor Cross Section (mm^2)	120 - 630
Diameter over Primary Insulation **D** (mm)	33.0 - 58.0

3M Deutschland GmbH		Issue: 1	Issue date: 02.02.2010

Please note: This product may only be assembled by trained specialized personnel according to these assembly instructions. The preceding specifications are the result of in-depth research. They correspond to the state of our experience. A test by you will convince you of the excellent properties of the 3M products. Verify yourself whether these products are suitable for your purposes. All questions regarding a warranty liability are governed by our terms of sale, unless legal provisions provide differently.

AABBCC75657		1. Issue date:	02.02.10
Language:	English	1. Change date:	
Drawn:	M. Hubrich	2. Change date:	
Checked:	J. Weichold	3. Change date:	
		4. Change date:	

3M QTEN

Molded Rubber Termination for Outdoor Application

96-EP 720-2

for single core plastic insulated copper wire screened cables acc. to IEC 60840

U_m = 72.5 kV

3M Electrical Products | **XE-0091-3568-4**

Figure 2.1: *Molded Rubber Termination*

Cross Section (mm^2)	Dimension **A** (mm)
120 - 400	700
500 - 630	650

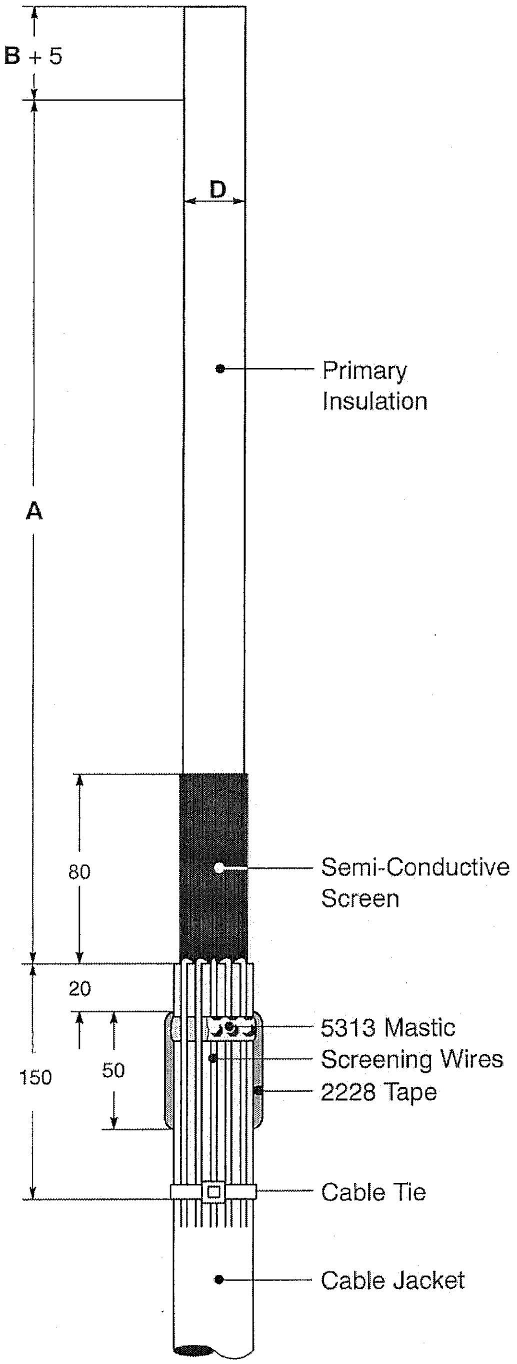

Fig. 1

1.1 Remove the cable jacket for **A** + **B** + 5mm.
1.2 Apply a 5313 mastic over the cable jacket.
1.3 Bend the screening wires back over the sealing and fix them with a cable tie
1.4 Wrap a second seal with 2228 tape over the screening wires and previously applied sealing.
1.5 Remove the semi-conductive screen leaving 80 mm in front of the cable jacket.

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Figure 2.2: *Molded Rubber Termination*

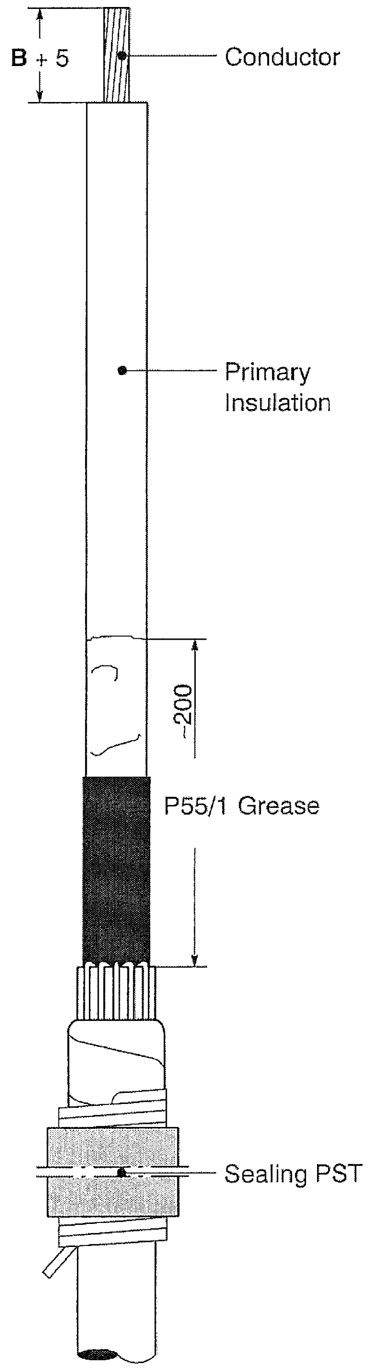

Fig. 2

2.1 Remove primary insulation acc. to dimension **B** + 5 mm.
B = Internal depth of lug barrel.

2.2 Slide the bigger sealing tube onto the cable jacket.

2.3 Apply 1 tube P55/1 grease onto the semi-conductive screen and the insulation for approximately 200 mm.

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Figure 2.3: *Molded Rubber Termination*

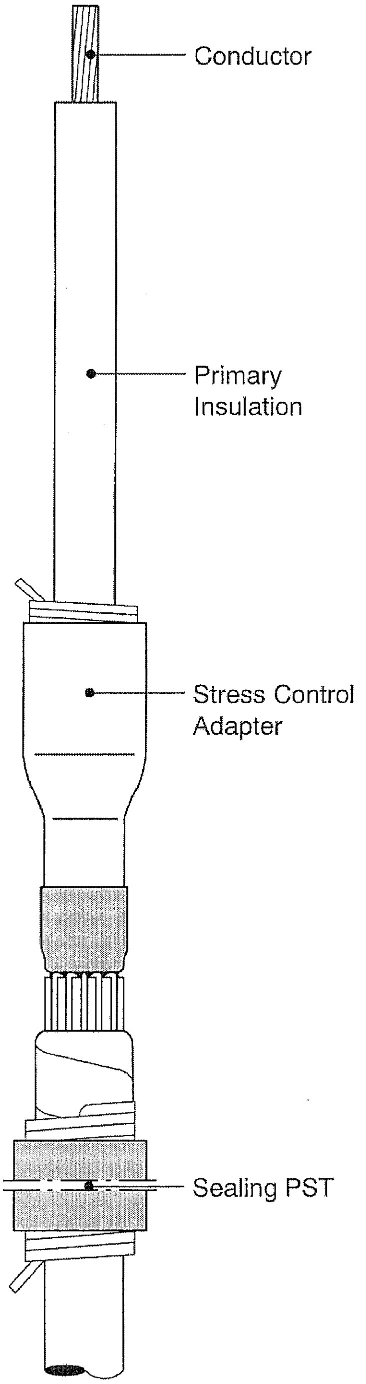

Fig. 3

3.1 Slide the Cold Shrink stress control adapter onto the cable with the loose core end towards the end of the cable.

3.2 Commence shrinking the stress control adapter at the outer sheath off position.

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Figure 2.4: *Molded Rubber Termination*

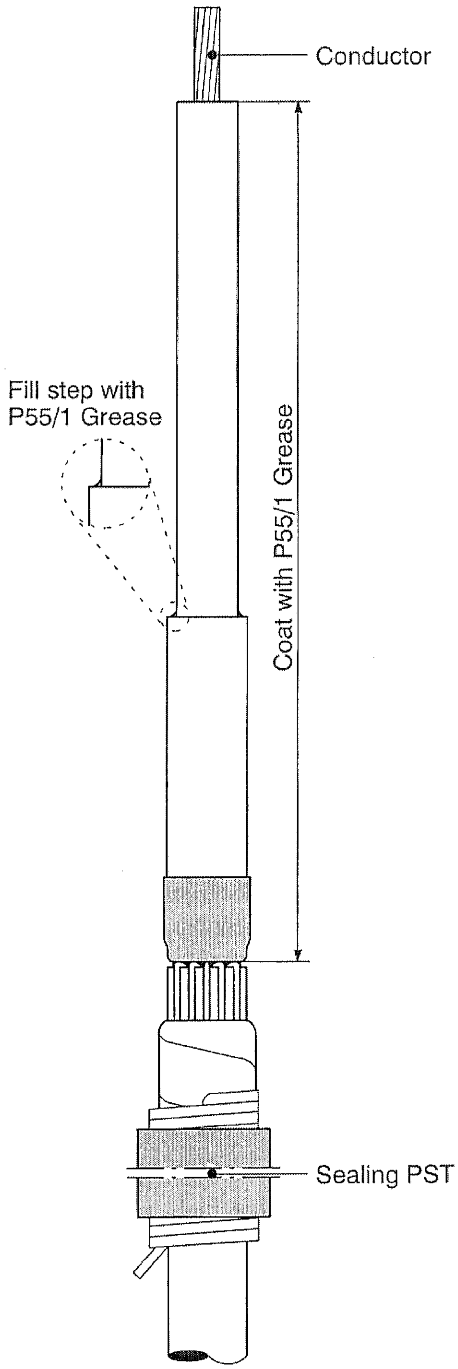

Fig. 4

4.1 Apply 2 tubes P55/1 grease to the exposed insulation and stress control adapter. Fill the top edge of the stress control tube with the P55/1 grease

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Figure 2.5: *Molded Rubber Termination*

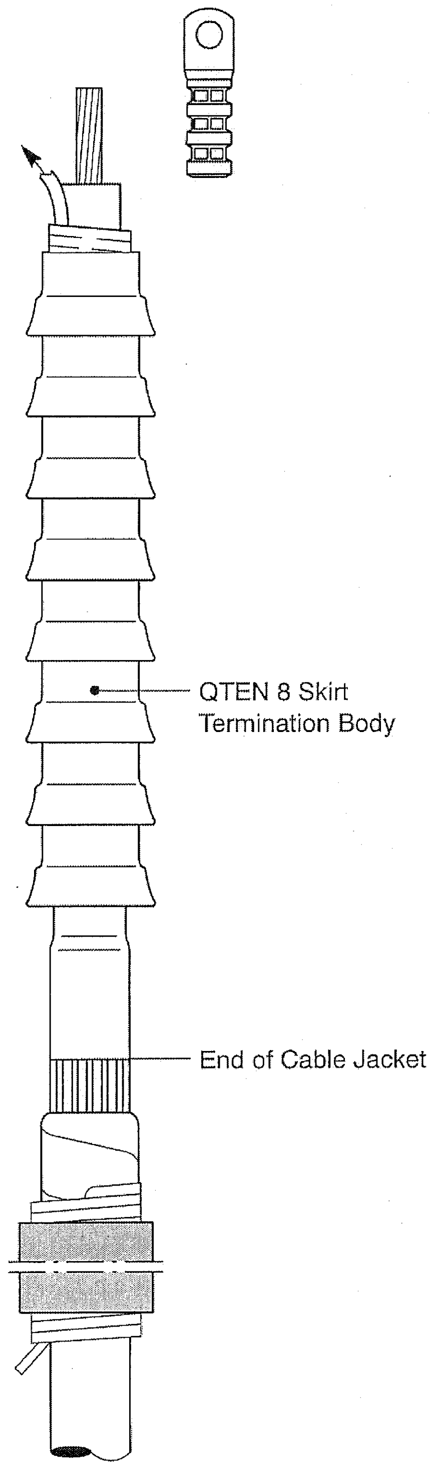

Fig. 5

5.1 Slide the QTEN 8-skirt termination body onto the cable. Remove the collapsible zip core by unwinding it in counter clockwise direction. Start to shrink at the end of the cable jacket.

5.2 If necessary carefully trim the termination body in line with the cable insulation.

Prüfgegenstand entspricht der vorgelegten technischen Zeichnung

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Figure 2.6: *Molded Rubber Termination*

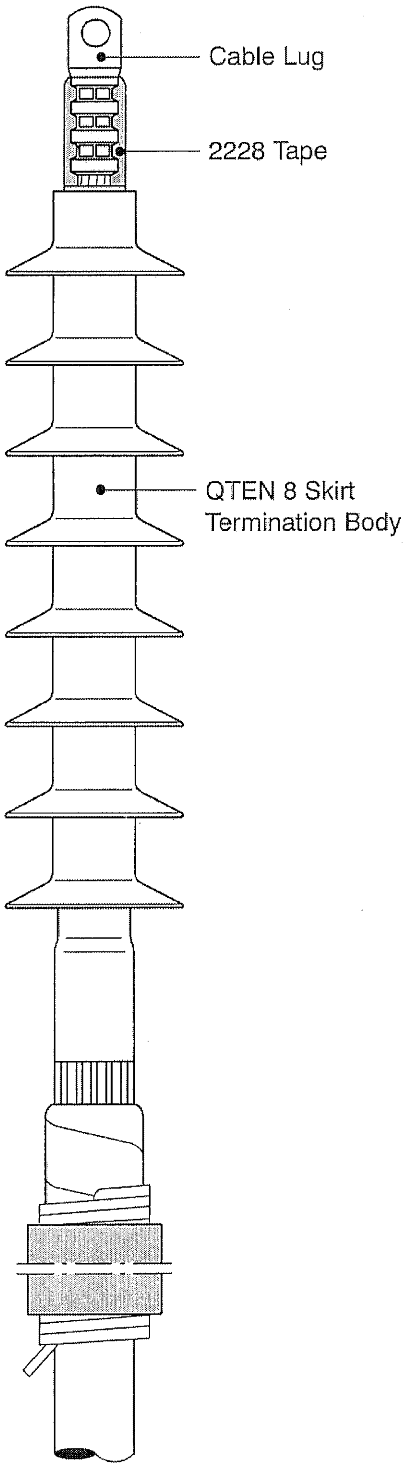

Fig. 6

6.1 Install the lug onto the conductor to manufacturer's instructions. Deburr, clean and smooth the lug.

6.2 Wrap two half-lapped layers of 2228 tape over the top lug. Fill the gap between lug and insulation.

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Figure 2.7: *Molded Rubber Termination*

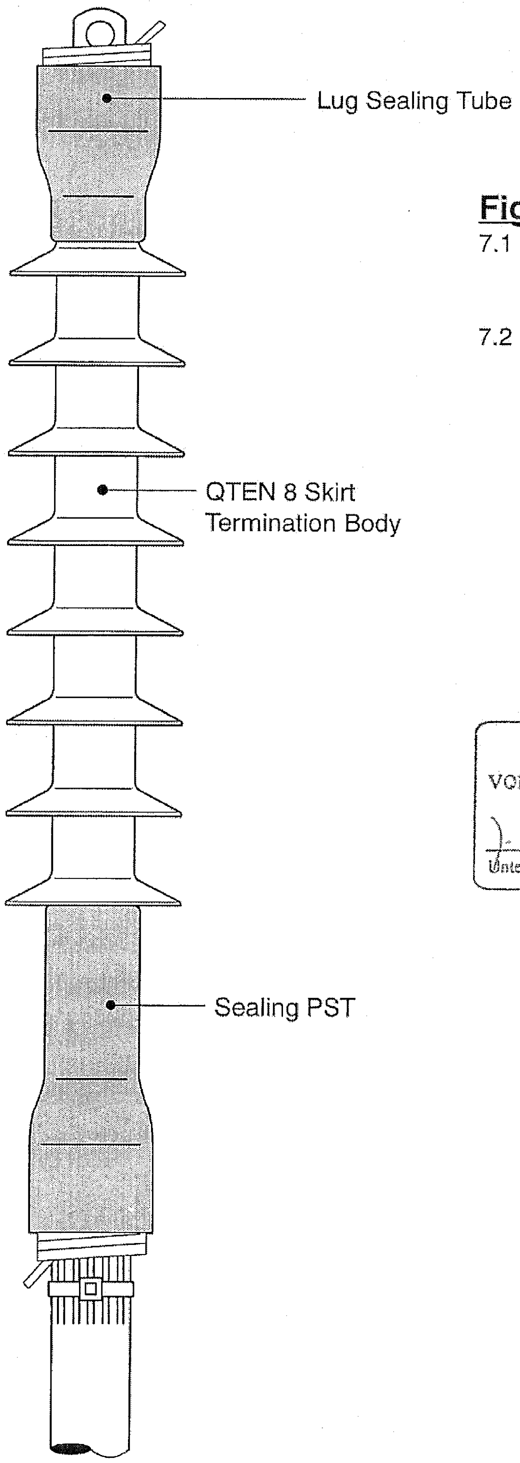

Fig. 7

7.1 Slide the parked sealing tube onto the termination. Start to shrink underneath the first skirt.

7.2 Slide the lug sealing tube onto the termination / lug. Start to shrink on top of last skirt. Carefully trim the sealing tube in line with the lug.

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Figure 2.8: *Molded Rubber Termination*

Material list

Outdoor Termination

No	Quantity	Description		96-EP 720-2	
1	1	QTEN 72 kV Termination Body		Size B2	
2	1	Stress Control Adapter		Size B	
3	1	Sealing PST (Cable Jacket)		38.3 x 305 x 133 mm	
4	1	Sealing PST (Lug)		25.4 x 229 x 83.3 mm	
5	1	Scotch® 2228 Tape		50.8 mm x 2.0 m x 1.65 mm	
6	1	Mastic Tape 5313		20 mm x 152 mm	
7	1	Vinyl Tape		min 15 mm x 10 m	
8	1	Cable Tie		FS-550 DW-C	
9	3	P55/1		4.5 ml	
10	2	Plastic Glove			
11	1	Installation Instruction, English		AABBCC75657	
12	1	Material List		AABBCC75665	

Prüfgegenstand entspricht der vorgelegten technischen Zeichnung

Unterschrift des Herstellers Unterschrift des Prüfers

AABBCC75665

Issue: 1

Date: 02.02.2010

Figure 2.9: *Material list*

Identification of Test Cable

Rated voltage U_0/U (U_m):	36/66 (72.5) kV		
Construction:	☒ 1-core		☐ 3-core
Conductors:	☒ Al		☐ Cu
	☒ Stranded		☐ Solid
	Cross-section:	1000 mm²	
Insulation:	☒ XLPE	☐ PE	☐ EPR
Insulation screen:	☒ Bonded	☐ Strippable	☐ Graphite
Metallic screen:	☒ Wires	☐ Tape	☐ Extruded
	Cross-section:	95 mm²	
Armour:	☐ Wire		☐ Tape
Oversheath:	☐ PVC		☒ PE
	☒ Laminated	☒ Al	☐ Cu
	☒ Conductive Layer		

Diameters:			
	Conductor	38,7	mm
	Insulation	59,5	mm
	Insulation screen	63,1	mm
	Oversheath	75,0	mm

Cable marking: Endesa KNE 001 –General Cable 4- HERSATENE-FOC RHZ+20L(S) 36/36 (72.5)kV-XLPE-1x1000 K AL+H95 06 0F 447930

Prüfgegenstand entspricht der vorgelegten technischen Zeichnung

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Figure 2.10: *Cable Data Sheet*

Tests: Test volume, chronological order and requirements conform to IEC 60840 04/2004 type test on cable accessories and additional customer´s specification.

Pos. 1 Check of insulation thickness

Pos. 2 Partial Discharge Test
$\hat{u} / \sqrt{2} = 1{,}75\ U_0 = 63$ kV 10 s thereafter ;
$\hat{u} / \sqrt{2} = 1{,}5\ U_0 = 54$ kV
no detectable discharge

Pos. 3 Heating cycle voltage test
Load cycle: 24 h
8h loading up to 95°C - 100 °C conductor temperature with at least 2h at 95°C-100°C
16h cooling
Test voltage: $\hat{u} / \sqrt{2} = 2{,}0\ U_0 = 72$ kV
Number of cycles: 20

Pos. 4 Partial Discharge Test
$\hat{u} / \sqrt{2} = 1{,}75\ U_0 = 63$ kV 10 s thereafter ;
$\hat{u} / \sqrt{2} = 1{,}5\ U_0 = 54$ kV
no detectable discharge

Pos. 5 Partial Discharge Test at elevated temperature
8h loading up to 95°C - 100 °C conductor temperature with at least 2h at 95°C-100°C
$\hat{u} / \sqrt{2} = 1{,}75\ U_0 = 63$ kV 10 s thereafter ;
$\hat{u} / \sqrt{2} = 1{,}5\ U_0 = 54$ kV
no detectable discharge

Pos. 6 Lightning impulse voltage test at elevated temperature
T = 95°C-100°C, at least 2h, $\hat{u} = 325$ kV,
10 impulses each polarity

Pos. 7 AC-voltage withstand test during cooling period
$\hat{u} / \sqrt{2} = 2{,}5\ U_0 = 90$ kV, t = 15 min

Pos. 8 AC-voltage withstand test
$\hat{u} / \sqrt{2} = 3{,}0\ U_0 = 108$ kV, t = 4 h

Pos. 9 Accessory examination

3 Mounting

The cable preparation, assembling and mounting of the cable system was accomplished by technicians of 3M Deutschland GmbH.

The length of the free cable between accessories was 6 m.

4 Test Setup

4.1 Check of Insulation Thickness

The insulation thickness was measured as described in IEC 60811-1-1, chapter 8.1. For measuring the insulation thickness a profile projector, with a magnification of 10 was used which allowed a reading of 0.01 mm.

4.2 AC Voltage Withstand Test

The test voltage was generated by a 360-kVA transformer. The voltage was measured with a capacitive divider (C_H = 351 pF; ratio = 10.000:1) and a peak voltmeter reading $\hat{u} / \sqrt{2}$. The primary side of the AC-transformer was connected to a motor-generator set consisting of a variable frequency DC motor and a synchronous generator with variable excitation. The generator delivers voltages from 0 ... 500 V with currents up to 1000 A.

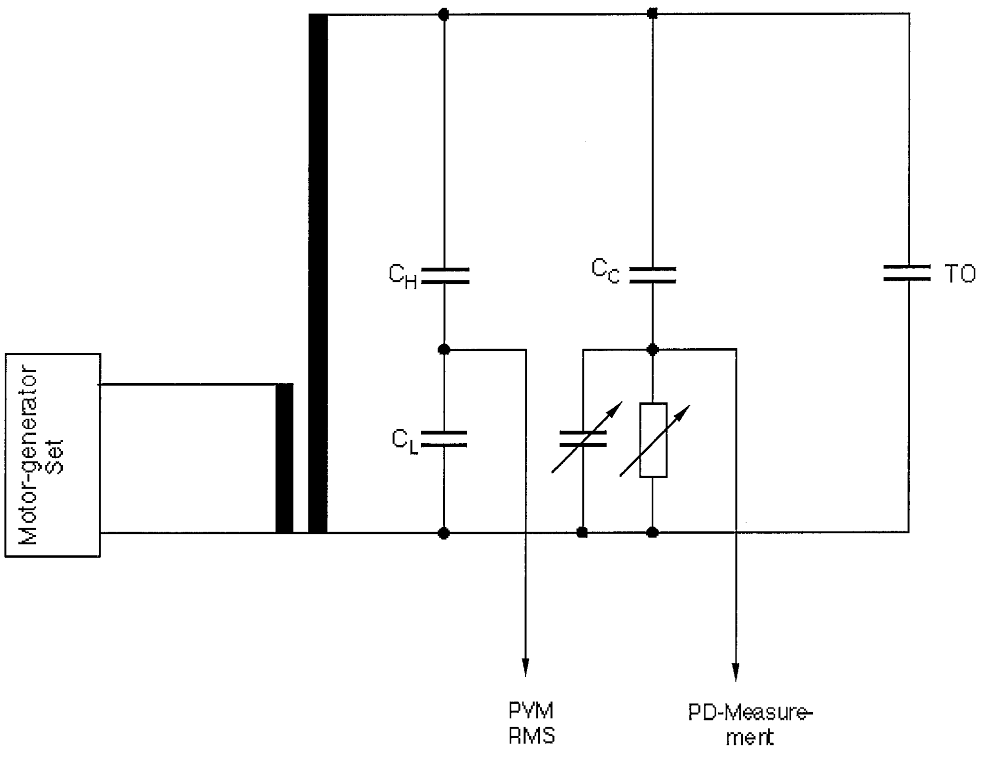

Figure 4.2: Test-setup for AC-voltage withstand test and PD measurement

AC-transformer:	500V/300kV; S_N = 360 kVA
Voltage measurement:	C_H = 351 pF; ratio 10.000:1 uncertainty 3 %
PD measurement:	C_C = 1000 pF; U_N = 800 kV_{rms} uncertainty 5 %

4.3 Partial-Discharge Test

The PD-measurement was performed with an analog bridge according to *Kreuger*, Figure 4.3. External PDs producing common mode signals at the detector are rejected by the differential amplifier. Internal PDs represent differential mode signals and are amplified. The background noise level at 54 kV_{rms} was 2.0 pC.

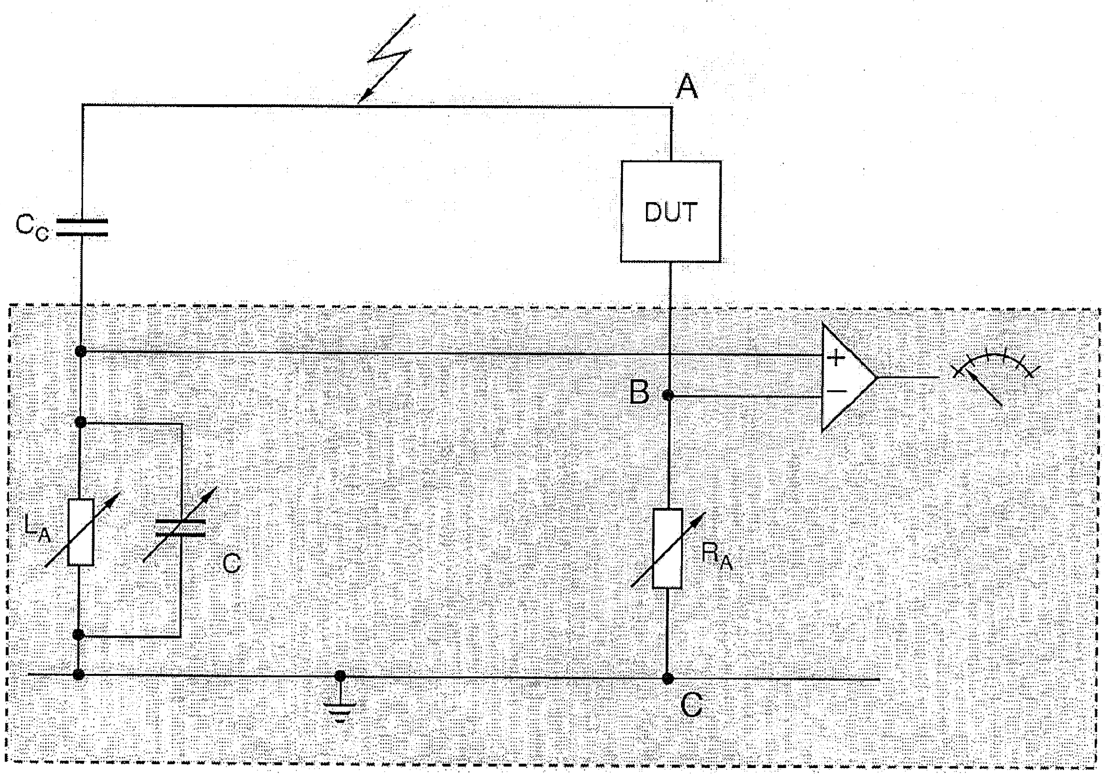

Figure 4.3: Scheme of PD test circuit
DUT : Test object
C_C: Coupling Capacitor

For balancing the bridge a calibrating impulse with q_A = 10.000 pC is applied between the terminals A (high-voltage) and C (ground) and the amplifier output is minimized. A pulse between the terminals A and C corresponds to an external PD. For the calibration a PD pulse, q_A = 5 pC, is applied between A and B. Subsequently, the amplifier output of the PD measuring unit is adapted to the applied pulse.

4.4 Cyclic Current Loading

According to IEC 60840 the test objects must be heated by a current which provides the permitted service temperature of the tested cable plus 5 K - 10 K, that means 95°C - 100°C, for XLPE-cable. The required heating current I was determined via a dummy cable. A 6 m sample of the cable used for the test, was provided with a 1 mm diameter drilling hole down to the center conductor. The temperature was measured with thermocouples NiCr-Ni. Two other thermocouples were installed on the conductor of the reference cable 0.5 m away from the middle and 1.0 m away from the middle. The difference between the three readings was less than 1°C. Furthermore two additional thermocouples NiCr-Ni were placed on the outer sheath of the cable, one on the dummy and one on the test loop. The max. heating current was I = 1600 A, 8h. Current inception was accomplished by a transformer (U_1 = 400 V; U_2 = 20 V) which used the cable as secondary winding. The current was regulated by a control unit and measured by a current transformer, 3000:1, and a digital multimeter. The measurement uncertainty was 1%.

4.5 Lightning Impulse Voltage Test

For lightning impulse testing of the cable 4 stages of a Marx generator (Haefely) with a maximum cumulative charging voltage of U = 800 kV and a maximum impulse energy of E_{max} = 40 kWs were used. The crest value of the impulse voltage was measured by a damped capacitive divider and a subsequent impulse peak voltmeter (Haefely). The time to crest and the time to half value were evaluated from the oscillographs.

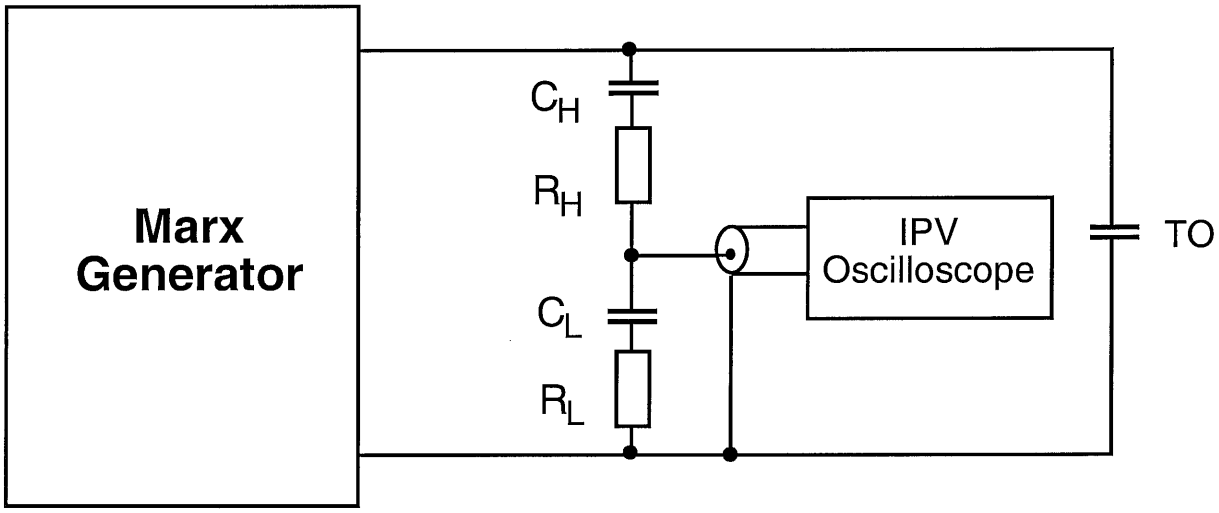

Figure 4.5.1: Scheme of lightning impulse voltage test circuit
C_H: 1200 pF ; R_H = 70 Ω ; ratio: 3225;
IPV: impulse-peak-voltmeter (Haefely) –
measurement uncertainty 3%
Oscilloscope: Tektronix TDS 3044 B – measurement uncertainty 2%

The waveform parameters were determined at reduced charging voltage. Figure 4.5.2 shows the front time, Figure 4.5.3 the time to half value for positive polarity each. Figure 4.5.4 shows the front time, Figure 4.5.5 the time to half value for negative polarity each.

Positive impulse: :	T_1 = 1.77 µs	T_2 = 49.8 µs
Negative impulse:	T_1 = 1.67 µs	T_2 = 49.8 µs

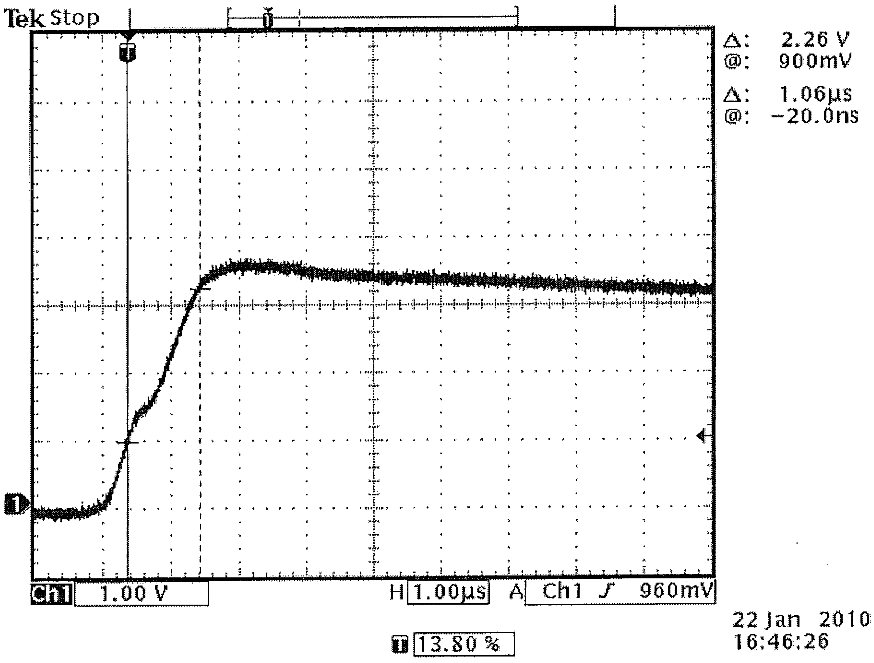

Figure 4.5.2: Front time, positive polarity
horiz.: 1 µs/Div; vert.: 1V/Div; probe 10:1; ratio 3225:1

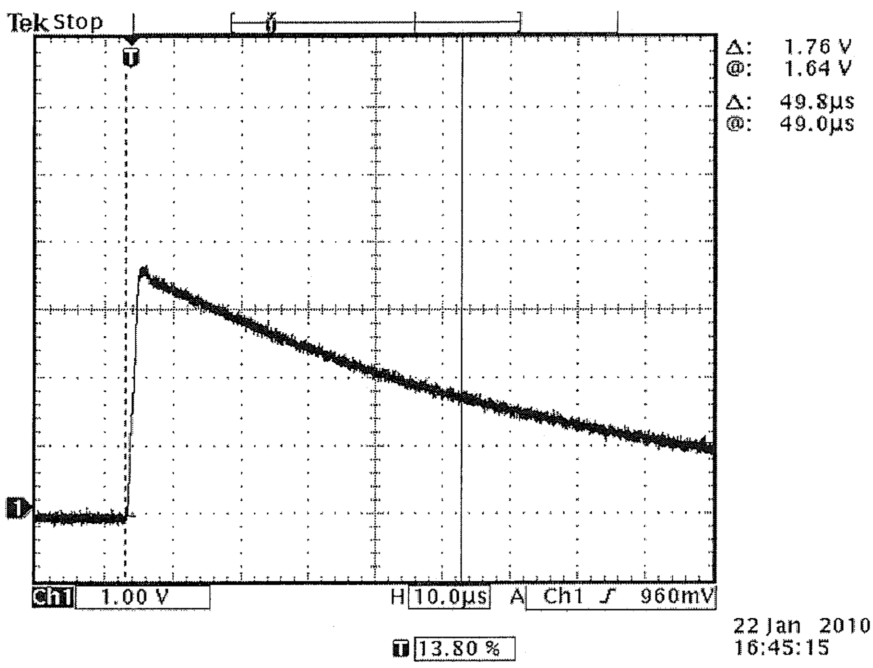

Figure 4.5.3: Time to half value, positive polarity
horiz.: 10 µs/Div; vert.: 1V/Div; probe 10:1; ratio 3225:1

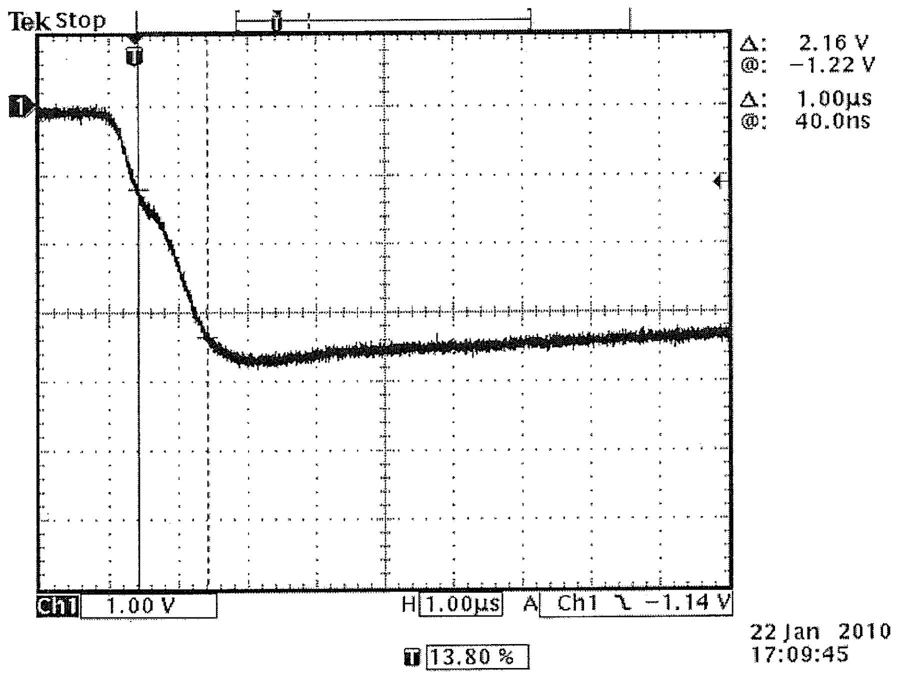

Figure 4.5.4: Front time, negative polarity
horiz.: 1 µs/Div; vert.: 1V/Div; probe 10:1; ratio 3225:1

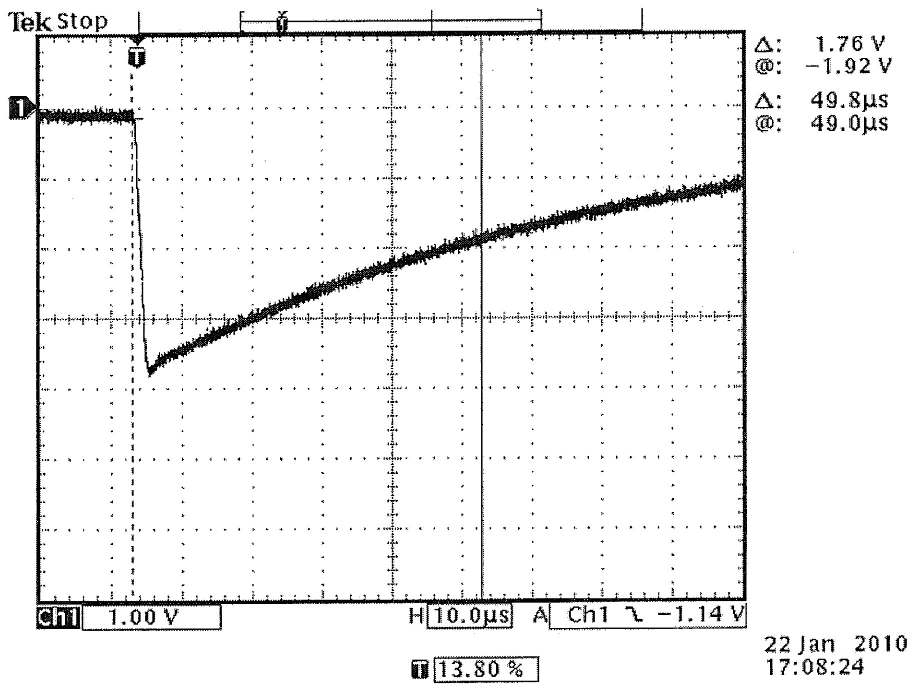

Figure 4.5.5: Time to half value, negative polarity
horiz.: 10 µs/Div; vert.: 1V/Div; probe 10:1; ratio 3225:1

4.6 Measuring Devices

Table 4.6 shows all used test systems and the measurement devices including calibration dates.

Inv No.	System	Type	Ser No	Manufacturer	Last Cal date	Next Cal date	Calibrated by
	AC Test System						
J 0650	Transformer	PT 60/200	83/41177	AEG			
990014	AC Measuring System	HVT 250 RCR	992.696	HILO-TEST	03/2009	03/2010	DKD-K-15901
	Heating System						
960001	Heating Transformer	GENN 250/1.1	9529994	HTT			
05-026040	Current Transformer 3000:1	GSA 300 B150		Schwarz+Graf	08/2009	08/2011	IEH
05-025267	Digital Multimeter	34401A	My 45011260	Agilent	08/2009	08/2010	IEH
04-017646	Temperature Measuring Syst.	5180V	GE49322-001-001-4704x37	Eurotherm	08/2009	08/2010	IEH
	Impulse Test System						
790033	Impulse Generator	SGVG 3600	180	Haefely			
790033/1	Voltage Divider	CR,3600kV SPR2	140090/91/92	Haefely	08/2009	08/2010	IEH
860074	Impulse Peak Voltmeter	64M		Haefely	08/2009	08/2010	IEH
05-025522	Digital Storage Oscilloscope	TDS 3044B	B010587	Tektronix	07/2009	07/2010	DKD-K-05352
	PD Measuring System						
920075	PD Measuring Bridge	9124 WQ	139741	Tettex	08/2009	08/2010	IEH

Table 4.6: Measurement devices

5 Results

5.1 Check of Insulation Thickness

The test was carried out as described in 4.

Test date:	15.12.2009
Nominal value:	9.0 mm
Measured Values:	9.07 mm
	9.06 mm
	8.78 mm
	8.70 mm
	9.14 mm
	9.19 mm
Average Value:	8,99 mm

Result: The average value goes below the nominal value by 0.11%, so no correction was necessary

5.2 PD-Test

The test was carried out as described in 4.

Test date:	18.12.2009
Calibration pulse:	$q_{cal} = 5$ pC
Background noise level:	0.7 pC
Test voltage:	$\hat{u}/\sqrt{2} = 63$ kV; t = 10 s, thereafter
	$\hat{u}/\sqrt{2} = 54$ kV; with pd reading
PD:	no detectable discharges

The test was passed successfully

5.3 Heating cycle voltage test

The test was carried out as described in 4.

Test date:	23.12.2009 – 12.01.2010
Test voltage:	$\hat{u}/\sqrt{2} = 72$ kV
Heating current:	I = 1500 … 1600 A regulated, 8 h I = 0A, 16 h
Cycle:	8 h heating; 16 h cooling
Number of cycles:	20

Neither breakdown nor flashover occurred.

The test was passed successfully

5.4 PD-Test

The test was carried out as described in 4.

Test date:	21.01.2010
Calibration pulse:	q_{cal} = 5 pC
Background noise level:	2.0 pC
Test voltage:	$\hat{u} / \sqrt{2}$ = 63 kV; t = 10 s, thereafter
	$\hat{u} / \sqrt{2}$ = 54 kV; with pd reading
PD:	no detectable discharges

The test was passed successfully

5.5 PD-Test at elevated temperature

The test was carried out as described in 4.

Test date:	22.01.2010
Calibration pulse:	q_{cal} = 5 pC
Background noise level:	2.0 pC
Heating current:	I = 1500 … 1600 A regulated, 8 h
Test voltage:	$\hat{u} / \sqrt{2}$ = 63 kV; t = 10s, thereafter
	$\hat{u} / \sqrt{2}$ = 54 kV; with pd reading
PD:	no detectable discharges

The test was passed successfully

5.6 Lightning Impulse Voltage Withstand Test at elevated temperature

This test was carried out as described in 4.

Test date:	27.01.2010
Test voltage:	$\hat{u}$ = 325 kV
Heating current:	I = 1500 … 1600 A regulated, 8 h
Impulse:	1-5µs / 40-60 µs
Number of tests:	10 positive polarity, 10 negative polarity

Neither flashover nor breakdown occurred at the test objects during all lightning impulse voltage tests.

The test was passed successfully

Table 1 shows the test results with positive polarity, table 2 with negative polarity.

number	charging voltage / kV	û / kV	Figure	remark
1	30,0	113,4		front time,
2	30,0	113,1		time to half value
3	43,0	163,1		50%
4	60,0	229		70%
5	76,6	292		90%
6	85,2	325	5.1	1. 100%
7	85,2	325	5.1	2. 100%
8	85,2	325	5.1	3. 100%
9	85,2	325	5.1	4. 100%
10	85,2	325	5.1	5. 100%
11	85,2	325	5.2	6. 100%
12	85,2	325	5.2	7. 100%
13	85,2	325	5.2	8. 100%
14	85,2	325	5.2	9. 100%
15	85,2	325	5.2	10. 100%

Table 1: Lightning impulse voltage withstand test, positive polarity

number	charging voltage / kV	û / kV	Figure	remark
1	- 30,0	- 112,6		front time,
2	- 30,0	- 113,1		time to half value
3	- 43,0	- 162,8		50%
4	- 60,0	- 228		70%
5	- 76,6	- 292		90%
6	- 85,2	- 325	5.3	1. 100%
7	- 85,2	- 325	5.3	2. 100%
8	- 85,2	- 325	5.3	3. 100%
9	- 85,2	- 325	5.3	4. 100%
10	- 85,2	- 325	5.3	5. 100%
11	- 85,2	- 325	5.4	6. 100%
12	- 85,2	- 325	5.4	7. 100%
13	- 85,2	- 325	5.4	8. 100%
14	- 85,2	- 325	5.4	9. 100%
15	- 85,2	- 325	5.4	10. 100%

Table 2: Lightning impulse voltage withstand test, negative polarity

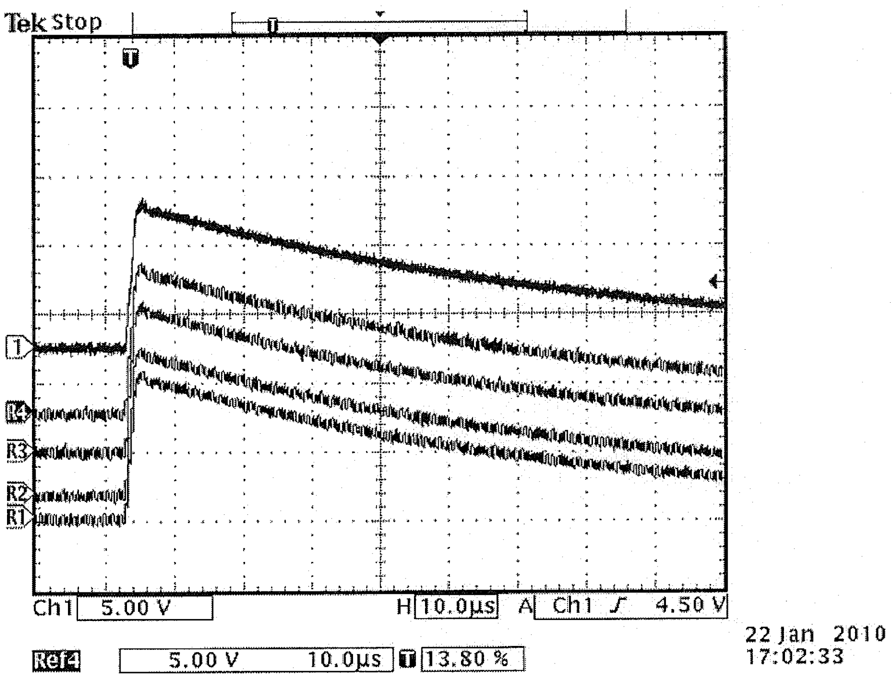

Figure 5.1: 100%-stress 1 - 5, positive polarity
Hor.: 10µs/Div; Vert.: 5V/Div; probe 10:1; ü = 3225

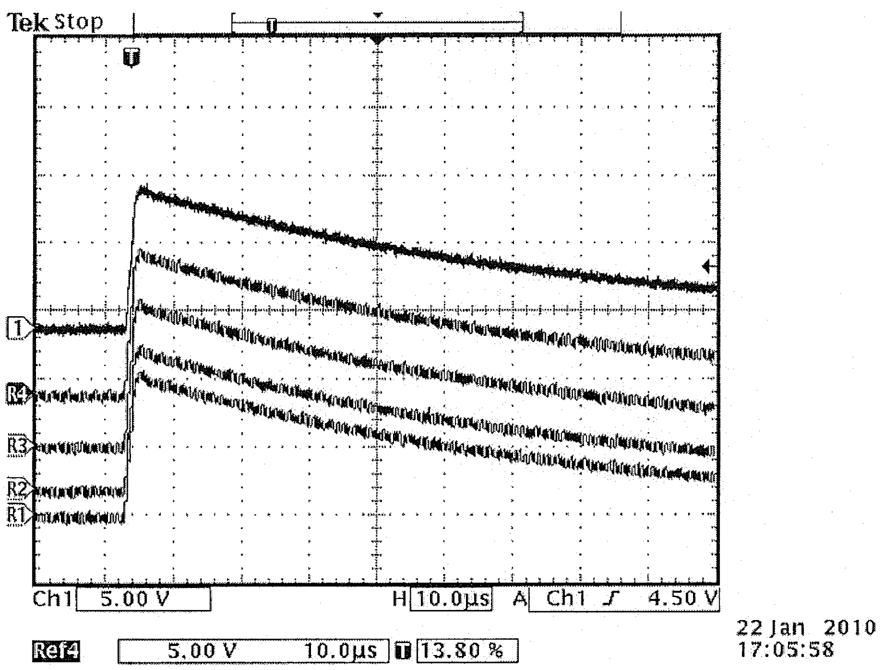

Figure 5.2: 100%-stress 6 - 10, positive polarity
Hor.: 10µs/Div; Vert.: 5V/Div; probe 10:1;ü = 3225

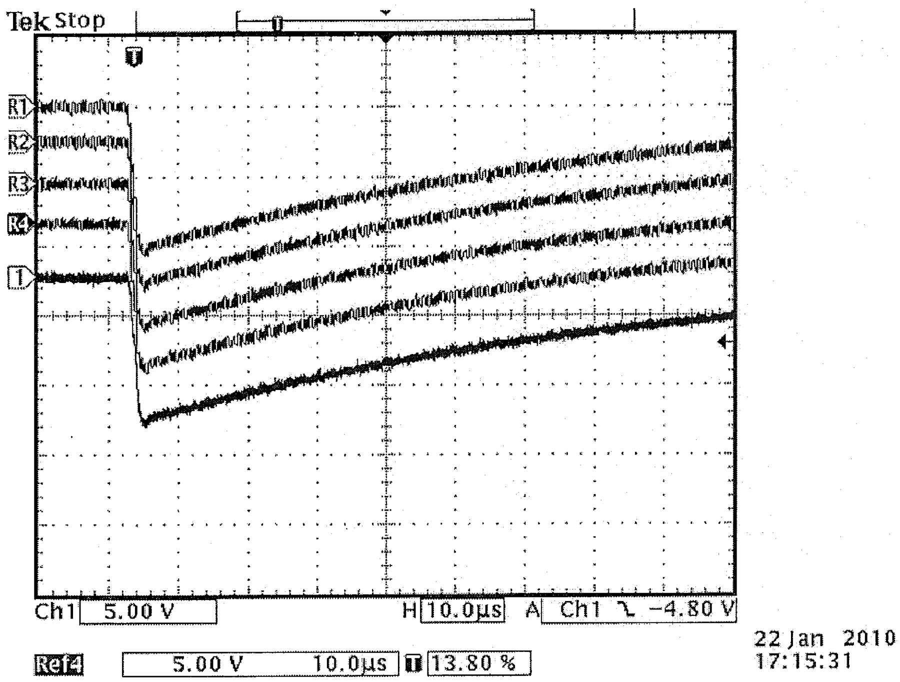

Figure 5.3: 100%-stress 1 - 5, negative polarity
Hor.: 10µs/Div; Vert.: 5V/Div; probe 10:1; ü = 3225

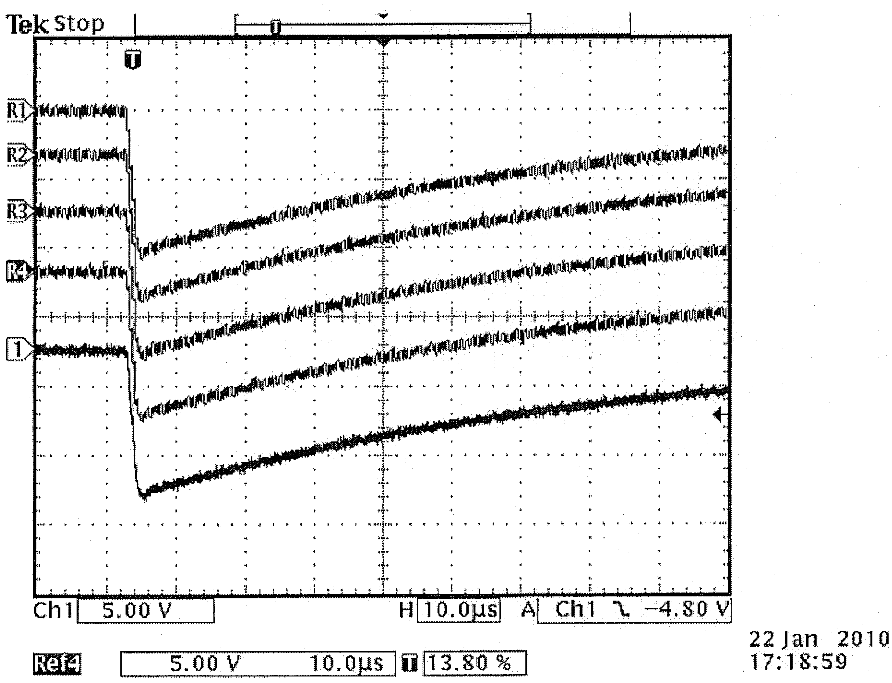

Figure 5.4: 100%-stress 6 - 10, negative polarity
Hor.: 10µs/Div; Vert.: 5V/Div; probe 10:1; ü = 3225

5.7 AC Voltage Withstand Test during cooling period

The test was carried out as described in 4.

Test date: 22.01.2010

Test voltage: $\hat{u} / \sqrt{2}$ = 90 kV; t = 15 min

Neither breakdown nor flashover occurred.

The test was passed successfully.

5.8 AC Voltage Withstand Test

The test was carried out as described in 4.

Test date: 28.01.2010

Test voltage: $\hat{u} / \sqrt{2}$ = 108 kV; t = 4h

Neither breakdown nor flashover occurred.

The test was passed successfully.

5.9 Accessory Examination

On completion of the electrical tests the termination was examined. There was no evidence of electrical activity.

The test was passed successfully.

6 Conclusion

The 72,5 kV- Molded Rubber Termination QTEN, manufacturer 3M Deutschland GmbH, passed all tests described in Chapter 2 successfully. The test object fulfilled the requirements according to IEC 60840 04/2004 type test on accessories and additional customer´s specification.

Karlsruhe, 18.03.2010

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